Meteorite Collection

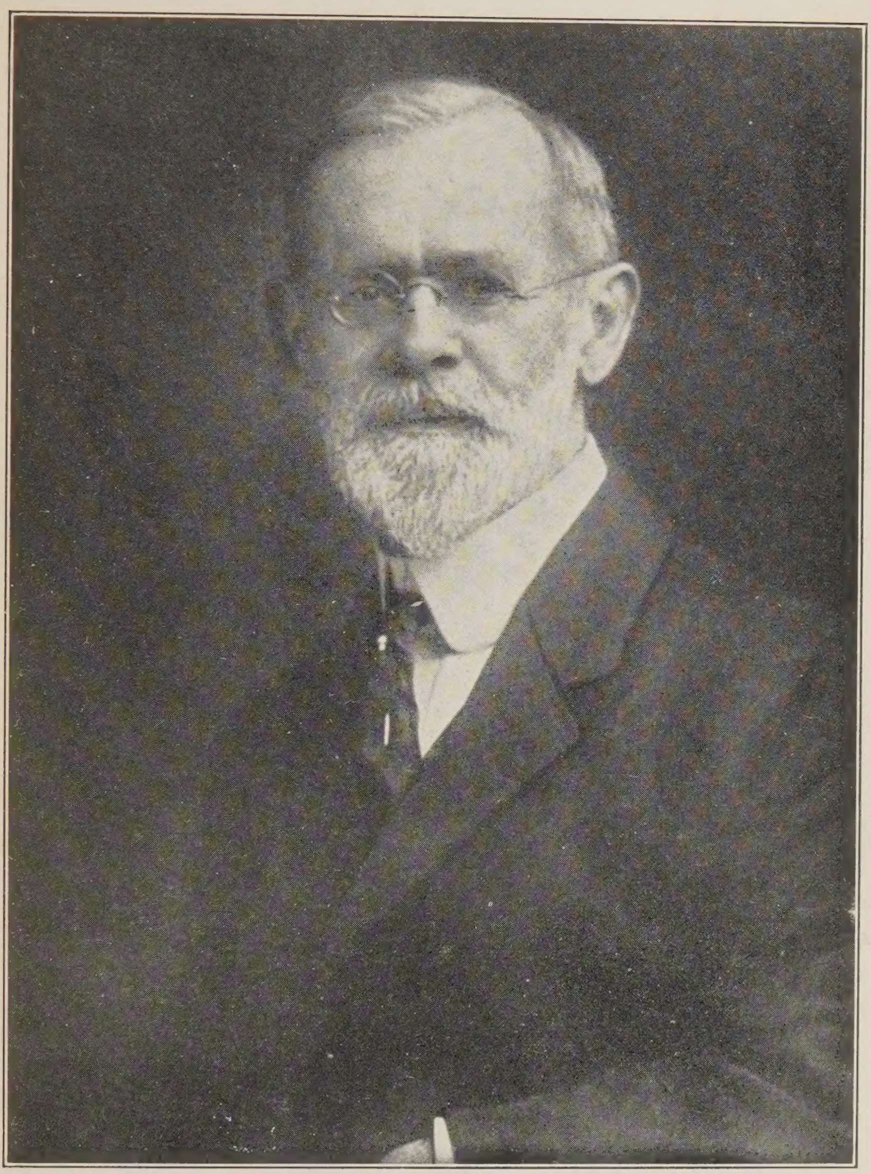
of

THE COLLEGE
of the
CITY OF NEW YORK

IVIN SICKELS, M. D.
Professor of Geology

MEMORIAL TO
CLEVELAND ABBE
Class of '57

1917



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Class of 1857.

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PREFACE.

This pamphlet is intended to convey an idea of the nature of those mysterious visitors to the earth called meteorites, and particularly to describe the many fine specimens recently presented to the College of the City of New York in memory of Prof. Cleveland Abbe, of the Class of '57.

The descriptive matter is taken largely from Bulletin No. 64, United States National Museum, written by Mr. George P. Merrill, Head Curator of Geology.

I. S.
July, 1917.

COLLECTION OF METEORITES.

INTRODUCTION.

"The study of meteorites unfolds a little the mystery of the Universe."

Coming, as these bodies do, from unknown realms outside of the earth we naturally associate them with the fixed and wandering objects of wonder in the heavens; and, since meteorites usually announce their advent by bright streaks of light, we speak familiarly of them as "shooting stars," or as "meteors."

Meteors may be observed both by day and by night. In the daytime, however, they are seldom noticed, for they appear merely as a long thin cloud which becomes wavy, gradually breaks up, and then fades away. At night, more often in the early hours of the morning, as the meteorite passes through the air, its surface, due to the friction produced by the extremely rapid passage, becomes intensely hot, and gives off a bright light, at times vivid enough to enable people to read, and even rivaling the sun in brilliancy. The light lasts but a second or two, ending abruptly. At times the meteor, before it disappears, is seen to increase in brightness, explode like a rocket, and continue in its course as several streams of light. Most meteors burn up in their passage through the air and never reach the earth. Frequently, however, they fall to the ground, and there are numerous instances where, following explosions of the larger stones, fragments have fallen to the earth, and thousands of pieces have been found scattered over a mile or more.

Scientists are not all agreed upon a definite theory of the origin of meteorites. Formerly we were inclined to accept the opinion that they were the remains of a planet-like body that had for some unknown reason been broken into pieces. At present we see that there is a possibility that molten matters thrown off during explosive eruptions in the sun, may receive such velocities that they would pass beyond the immediate control of the sun and assume orbital paths in the interplanetary spaces.

Astronomers engaged in the study of the sun's activities are taking thousands of photographs of flying fragments and incandescent matters cast off by the sun. These fragments rise to great, almost

inconceivable, altitudes above the sun's atmosphere before they are lost to view. And, perhaps, influenced by the attractions of planets and even stars, they remain in space to become members of that multitude of objects—planets, satellites, asteriods, comets and meteorites—that constitute our solar system.

This theory of the origin may also account for the crystalline structure of meteorites. We can readily believe that the iron and stone masses had already crystallized or were near the point of crystallization when thrown from the sun.

Another theory of the origin of meteorites, which appeals to our imagination, regards the concentration of radiant matter to form bodies in the interstellar spaces. The study of radium has of late proved that all substances undergo incessant disintegration with loss of radiant matter which passes into space. Not only is there a great quantity thrown off from the sun and the earth, but presumably also from planets and other celestial bodies. It is possible that in space the magnetic properties of this radiant matter might cause a recombination to form denser and even solid material such as is conveyed to us in the form of meteorites and which we now can study in museum collections like the classic one assembled here.

Also in connection with these theories of the origin we should consider the recent discovery of the coincidence of the periodic appearance of meteors with the paths of certain comets.

In olden times these falling stones were regarded with superstition and even with veneration. A noted example of this is the sacred black stone set in the wall of the Kaaba at Mecca.

By means of such fallen meteors we learn facts which advance our knowledge of celestial bodies. To explain the occurrence of these curious stones we must apply our knowledge of astronomy, the study of the infinitely great as revealed by the telescope, our knowledge of the structure of minerals and rocks as revealed by the microscope and polariscope and our knowledge of the now comprehensible atom, the infinitely small, as made known to us through the study of radium, although no meteorite has yet been found containing radium.

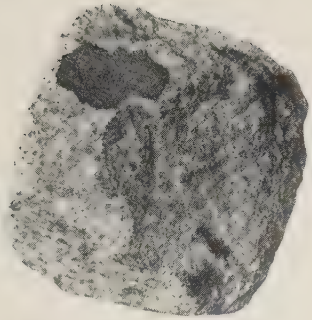


Fig. 1. Bjurbole Stone.

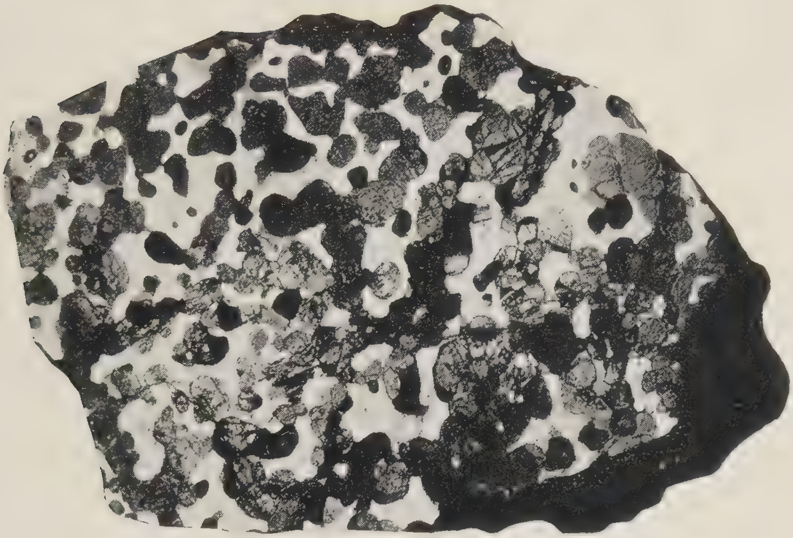


Fig. 2. Brenham Stony-iron.

Fig. 5. Estacado Stone.

CLASSIFICATION OF METEORITES.

Meteorites are grouped according to their composition. Commonly they are called either "irons" or "stones" depending on the predominance of metals or of rock-forming materials. More scientifically they are arranged into three generic groups:

Aerolites, chiefly silicates with very small quantities of the iron alloys;

Siderolites, silicates in a mesh or sponge of nickel-iron;

Siderites, essentially alloys of nickel-iron.

The aerolites are further separated into more specific groups depending upon the nature of the minerals which predominate in their structure, and the presence of peculiar spherical or oval shapes (chondrules) which are of particular and puzzling interest. The siderolites are again classified according to the mineral contents of the spaces inclosed by the metallic mesh of nickel-iron. The siderites, composed almost wholly of nickel-iron, are subdivided with respect to their crystallization into octahedral, hexahedral and massive.

COMPOSITION.

The minerals found in meteorites are essentially those of igneous origin. The elements composing them are the same as found on the earth, but in many the form of combination is of a radically different nature from that of terrestrial minerals, indicating conditions in the source of meteorites unlike those existing on the earth.

The most common of the silicate minerals is olivine, a magnesium iron silicate. Other minerals are members of the pyroxene and feldspar groups, oxids of iron and chromium, sulfids of iron, a rare carbonate and elementary carbon in the form of graphite and diamond. Besides the above, which are also terrestrial forms, there are several alloys of iron and nickel, together with a number of other compounds which are not found on the earth. Gasses, particularly nitrogen, hydrogen and the carbon oxids, have been found in meteorites.

A meteorite is a body of more than immediate mineralogic or petrographic interest. It furnishes tangible testimony of the nature of materials existing outside of our solar system, and affords aside from the spectroscope, the only clue to the matter of which celestial bodies are composed. The German, Chladni, as long ago as 1794, advocated their cosmic origin, and designated them "Welts-

päne" (world chips), or the remains of worlds gone to pieces, and from which other worlds might be built up. This idea with various modifications has been many times reasserted, but whatever theory one may accept as to world formation, the ultimate source of the materials remains the same.

It is known that the iron or metallic meteorites consist essentially of alloys of iron, nickel and cobalt, with which are commonly associated the iron phoshid (schreibersite) and the iron sulfid (troilite). In minute quantities there may be other constituents, as copper, chromium and various silicate minerals. It is in these metallic forms also that have been found the rarer elements—platinum, iridium, ruthenium, vanadium and possibly gold. Farrington's tabulation of analyses seems to show that the nickel content varies with the texture, the higher percentages of this constituent being found in those of finest crystallization.

STRUCTURE.

Thin slices of the stony meteorites are examined with the microscope to determine the kind and character of the minerals of which they are composed. Of particular interest are the chondrules, which have given rise to many theories regarding their origin and formation; they are very characteristic of some aerolites.

More picturesque are the beautiful markings obtained by etching polished surfaces of the irons. In the octahedral meteorites these markings are called "Widmanstätten figures" and are caused by the unequal solubilities of the three different alloys of iron and nickel present. The size of the crystals and the variable amount of each alloy seem to characterize each individual fall. To quote from "Meteorites" by O. C. Farrington:

"Although the nickel-iron of meteorites appears in a polished piece to be a homogeneous substance of uniform composition, investigation shows that it is in reality a complex substance, made up of alloys containing different quantities of nickel. The existence and character of these alloys is easily made evident by subjecting a polished surface of the nickel-iron to the action of heat, acids, or other etching agent. Figures of a more or less banded character then appear on the surface of the iron showing its complex structure. The discovery of this means of investigating the character of nickel-iron was made by Alois von Widmanstätten of Vienna in 1808."

The hexahedral irons show evident cleavage parallel to the faces of a cube and show lamellae due to the twinning of a cube on an

octahedral face. The etchings on these irons are called "Neumann lines."

Amorphous irons do not show markings when treated with acids.

PHENOMENA OF FALL.

The fall of a meteorite is usually accompanied by noises variously described as resembling the fire of musketry, cannonading, or even thunder. If the fall takes place during periods of darkness it is also accompanied by a flash of light and followed by a luminous rocket-like trail. These phenomena are due to the rapid passage of the objects through the air, and the consequent rise in temperature which is sufficient to produce fusion of the outer surface and even ignition, thus giving rise to the thin, dark, glass-like crust which is found coating all stony meteorites. The time of passage through the air is, however, too short to permit the heat to penetrate to great depths, and nearly all meteorites are quite cool or scarcely warm, on reaching the surface of the ground. The breaking up of a meteorite and its reaching the earth as a shower of fragments rather than a single individual, is due to the sudden rise of temperature, and to the pressure of the atmosphere.

VELOCITY OF METEORITES.

We have little to guide us in estimating the speed at which a meteorite reaches the earth and its consequent power of penetration. The velocities as given by different observers vary between 2 and 45 miles a second. These last, however, are the initial velocities, the velocities possessed by the meteors on entering our atmosphere and while still at considerable altitudes (in some instances 50 or 60 miles) and which become very materially reduced by atmospheric friction long before reaching the earth. Indeed from the calculations of Schiaparelli and others, it is commonly assumed that a meteorite reaches the surface at the speed of an ordinary falling body.

It is a noteworthy fact that the members of different meteor showers exhibit visible features which in certain cases are quite dissimilar. This arises from the circumstance that the various showers encounter the earth at different angles, and their apparent speed depends in a great measure upon this. Thus the meteors of November 13 (Leonids) are moving in a direction opposite to the earth; hence their velocity is very great, being about 44 miles per second. But the meteors of November 27 (Andromedes) are moving in nearly the

same direction as the earth, and hence have to overtake us, so that they apparently move very slowly, their speed being only 11 miles per second. The Leonids above referred to, together with the Perseids of August 10 and the Orionids of October 18-20, are good examples of the swift-moving meteors, and they are almost invariably accompanied by phosphorescent streaks. The slow meteors, of which the Andromedes are a type, throw off trains of yellowish sparks.

The result of investigation may be said to have created a strong presumption in favor of the following general deductions:

(a) That the velocities of meteorites are materially changed by the resistance of the atmosphere, and, in general, by a fractional part of the velocity which is independent of the velocity of the approach.

(b) That the superior limit for incandescence is probably about 150 miles above the earth's surface, and

(c) That no iron meteor the original weight of which was less than 10 to 20 pounds reaches the earth's surface, and that when a meteor does so, the temperature of its center is not in general above that of liquid air (assuming the temperature of space to be zero).

Owing to their extremely contradictory character, all statements relative to the temperature of meteorites immediately after reaching the ground must be accepted guardedly. According to Haidenger, some stones which fell in Styria in 1859 continued in a state of incandescence for from five to eight seconds, and for a quarter of an hour were too hot to be handled without burning. Beinert, in his account of the Braunau iron, states that for six hours it also remained too hot to be handled. On the other hand, the Dhurmsala stone is stated to have been intensely cold when picked up immediately after falling.

The reports of the setting of fires by the falling of meteorites must also be taken with the same degree of allowance. In the cases of both the Allegan and Winnebago falls the stones struck on the dried grass, which, though pressed closely against the surfaces, was not charred in the least. Indeed, one of the Winnebago stones fell on a stack of dry straw, but without igniting it.

NUMBER OF FALLS AND WEIGHT.

Upward of 650 falls and finds of meteorites have been reported, representatives of which have found their way into museums and private collections, and are there preserved for study and investigation. These, however, constitute a very small fraction of those which actually fall and are never recovered, since it is estimated that up-

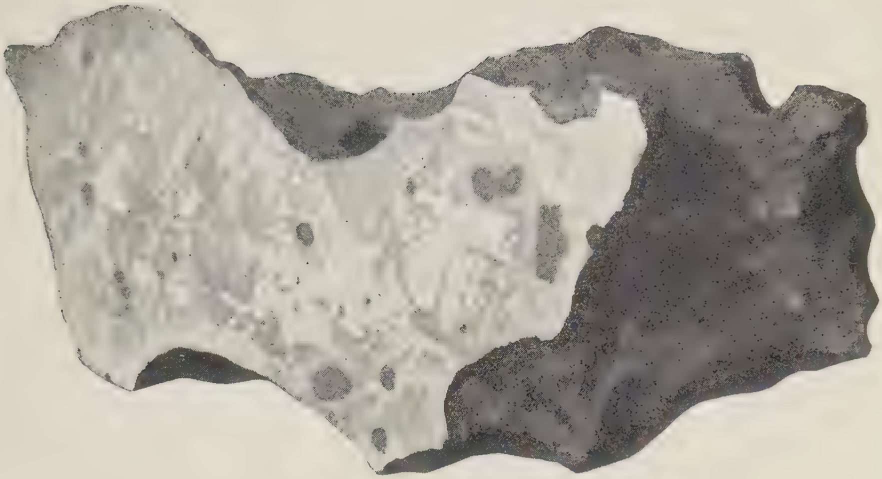


Fig. 3. Canyon Diablo Iron.

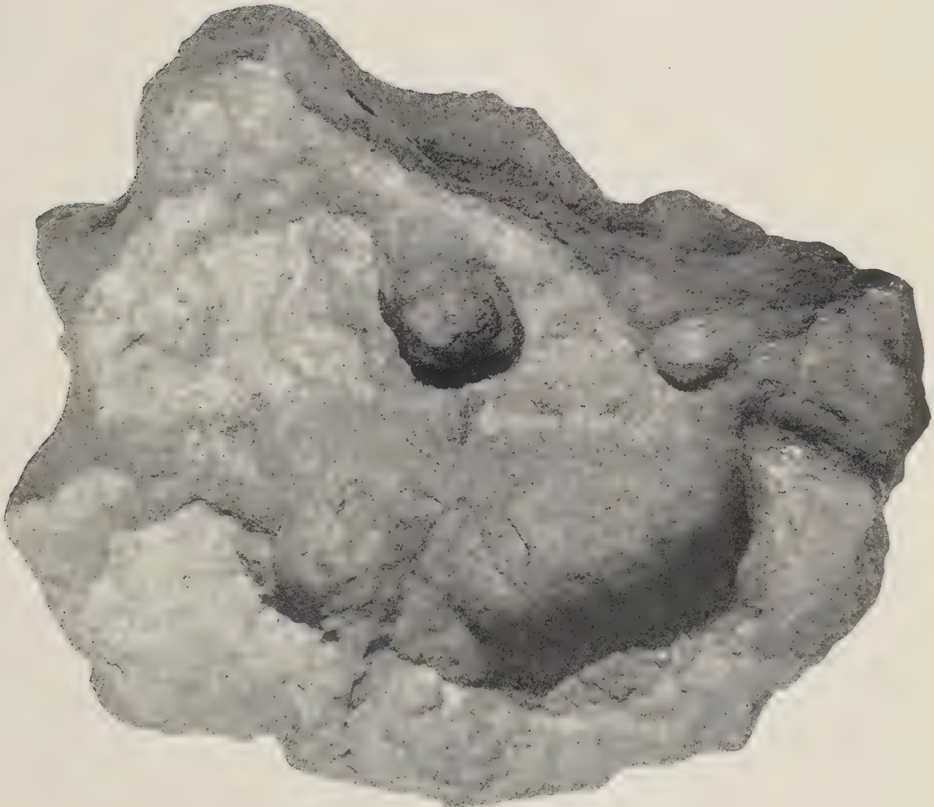


Fig. 4. Canyon Diablo Iron.

Fig. 6. Gibeon Iron.

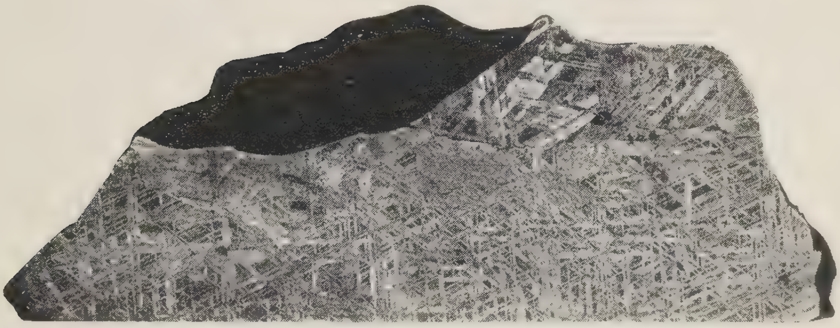


Fig. 7. Gibeon Iron.

Fig. 8 Gilgoin Station Stone.

wards of 20,000,000 strike the earth daily. These are for the most part very small, perhaps scarcely more than a grain in weight. It is interesting as well as singular that of all that have been seen to fall and have been recovered, but nine are of iron. The largest known meteoric mass (Ahnighito) is that brought by Commander Peary from Cape York, Greenland, and now in the Museum of Natural History, New York. This weighed 73,000 pounds. The next largest lies in the plain near Bacubirito in Mexico, and has been estimated to weigh some 50,000 pounds, while the third is that of Willamette, Oregon, weighing 31,107 pounds. These are all iron meteorites. The largest known individual aerolite or meteoric stone is that of Knyahinya, Hungary, weighing some 550 pounds, now in the Vienna National Museum.

It may be added, in conclusion, that all known meteorites are of an igneous nature and have yielded no traces of animal or vegetable life, although the peculiar radiating and grate-like structures of the chrondrules were at one time mistaken for organic remains.

ABBE COLLECTION OF METEORITES IN THE LINCOLN CORRIDOR OF THE COLLEGE OF THE CITY OF NEW YORK

Besides the many entire specimens there are slices cut from historic meteors by which we share with collections in European museums and our own National Museum these interesting objects which give the student a startling sense of the wonders of infinite space.

One example is arranged to illustrate the way in which a shower of fragments was found on the surface of the prairie, at Holbrook, Arizona. The fall occurred at sundown and was witnessed by farmers, who heard a roaring sound and saw puffs of dust over acres of ground. Over fourteen thousand pieces were recovered from an area of two miles. More than three hundred of these are here exhibited.

Other interesting specimens are the irons from the Meteor Crater, near Canyon Diablo, Arizona. Interesting not only because of the many thousands of pieces found around about the crater, but also because of the inferences which must be drawn from the way in which the rocks, normally horizontal, have been hollowed out and thrown up into a circular hill, nearly a mile in diameter. The crater

itself is several hundred feet deep. On the south side the limestone and sandstone strata have been tilted to an almost vertical dip.

We believe that a comet-like celestial body struck the earth here with such force that it crushed the layers of rock and buried its mass, estimated at millions of tons, deeply into the earth. Strewn around, within a radius of six miles, is found its train of iron followers.

Furthermore, because of the close resemblance of this crater to those on the surface of the moon, we infer that our satellite has received many impacts of similar nature in ages long gone by, perhaps when the moon was still warm or in its plastic stage.

Arranged alphabetically the meteorites in the collection are:

BJURBOLE, near Borga, in Southern Finland. Fig. 1.

A fragment from a stone which fell March 12, 1899, striking on the frozen surface of a lake, breaking through the ice which was about an inch in thickness, and burying itself in the clay at the bottom where it was found broken into numerous pieces. The aggregate weight was 328 kilograms, or 721 1-2 pounds. It consists of small round veined chondrites, and is of an ash gray color. Note the remaining piece of outside crust.

BRENHAM, Kiowa County, Kansas. Fig. 2.

This is an end slice of one of several masses found at Brenham, Kansas, between 1885 and 1888. It shows the characteristic surface pittings and is composed chiefly of a sponge-like mass of nickeliferous iron, with grains of olivine filling the pores. Troilite is also present. It is a stony-iron pallasite.

CANYON DIABLO, Arizona. Fig. 3 and Fig. 4.

The masses here shown are characteristic samples selected from a large number of irons, aggregating several tons in weight, found on the plains near what is locally known as Meteor Crater, some ten miles southeast of Canyon Diablo. There is no record of this fall, but the occurrence is remarkable not merely on account of the large amount of material, but from the fact that the iron contains minute black and white diamonds. The large cavities shown in the irons were probably once occupied by troilite (iron sulfid) which has weathered out during their long exposure on or near the surface of the ground. The octahedral character and coarse lamellar crystallization of this iron is shown on the etched surfaces in the case. The following analysis is given:

Silicon	Trace
Sulfur	0.009%
Phosphorus	.261
Manganese	None
Copper	.015
Nickel	7.335
Cobalt	.510
Combined carbon	.105
Graphitic carbon	.028
Iron oxids	2.520
Iron protochlorid	.097
Iron	89.167
	100.047

ESTACADO, Crosby County, Texas. Fig. 5.

This is a portion of a meteoric stone which weighed about 638 pounds, and is supposed to have fallen in 1882. The polished surface shows a dull black groundmass, thickly sprinkled with grains of nickel-iron, and containing also enstatite and olivine with pyrrhotite and chromite. The stone is a crystalline chondrite consisting of 83.59 per cent. silicates and 16.41 per cent. metallic constituents. The original mass exceeds in size any known meteoric stone.

FOREST CITY, Winnebago County, Iowa.

The stones here shown formed part of a shower which fell in Winnebago County, Iowa, on Friday, May 1, 1890, at 5.15 p. m.

The meteor, when first observed, had the appearance of a bright ball of fire moving from west to east, leaving behind it a trail of smoke which remained visible for ten or fifteen minutes. It exploded about eleven miles northwest of Forest City, with a noise compared by some to thunder, and by others to heavy cannonading, scattering the fragments over an area about one mile wide and two miles long. Some five hundred individuals, weighing from half an ounce to 80 pounds each, have been found. The stone is of the breccia-like chondritic type and consists of 19.4 per cent. nickeliferous iron, 6.19 per cent. troilite, and 74.41 per cent. of silicate minerals, mainly olivine and enstatite, with a little feldspar.

GIBEON (Mukerop), Great Namaqualand, Southwest Africa. Fig. 6 and Fig. 7.

This siderite was found near the Bethany District of Gibeon,

and is represented here by an end piece, etched on two polished sides, weighing 18 1-2 pounds. The entire meteorite weighed 178 kilograms or 477 pounds. It was found in 1899.

An interesting feature of the small etched face on this specimen is that it shows three zones of crystallization, as though three differently oriented masses had been welded together.

GILGOIN STATION No. 2, near Brewarrina, New South Wales. Fig. 8.

A crystalline chondritic specimen, cut and polished on three sides. The most striking feature of the stone is the abundance of small, wavy, nearly parallel fracture lines, which may have been produced by impact with the earth, or by shearing stresses in the mass itself.

GRAND RAPIDS (Walker Township), Kent County, Michigan. Fig. 9.

An etched slice, showing distinct Widmanstätten figures, and weighing 965 grams. Found in 1883. Nothing is known regarding this fall. Its composition is mostly of nickel-iron.

HOLBROOK, Navajo County, Arizona.

This is one of the most interesting of all falls, mostly due to the fact that its fall was witnessed on July 19, 1912, at Holbrook, Navajo County, Arizona. On this date thousands of individual specimens were strewn over the ground in this locality for a considerable distance, varying in size from that of a pea up to specimens of four and five hundred pounds.

One of the questions that will arise among those studying this particular fall will be, how such small particles could travel through space at such velocity as to become fused to the extent that a crust, similar to the large specimens, has formed, and like the larger specimens, a reformation of crusts over fractured parts has taken place.

This material is a compact, light gray, chondritic stone, showing very little metal, but comparatively numerous nodules of troilite. The mineral composition is olivine, with monoclinic and orthorhombic pyroxenes, and a small amount of glassy material which may be maskelynite.

Fig. 9. Grand Rapids Iron.

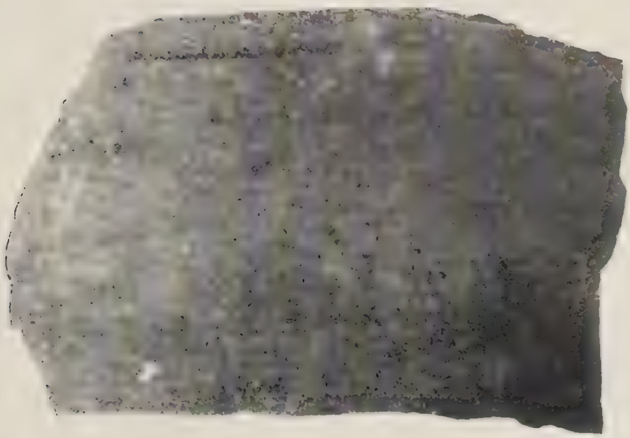


Fig. 10. McKinney Stone.

An analysis of the stone gives the following:

Silica	36.68%
Alumina	3.76
Ferrous oxid	19.11
Lime	2.10
Magnesia	25.46
Manganous oxid	.22
Nickel oxid	.07
Nickel	.42
Cobalt	.03
Copper	.01
Iron	4.39
Ferrous sulfid	7.56
	99.81

KNYAHINYA, Hungary.

Complete specimen, with crust; weighing 211 grams. Fell June 9, 1866. Its structure is chondritic with an ash gray, granular, compact groundmass. The original fall consisted of over 1,000 stones, weighing upward of 500 kilograms, or 1,100 pounds. This is one of the most interesting of stony meteorites owing to the very full data of Haidinger regarding its fall, as well as on account of the number of stones. It was studied in thin sections by Kenngott in 1869, who recognized the presence of enstatite, olivine, troilite and native iron. These results have since been confirmed by Wadsworth.

LLANO del INCA, Desert of Atacama, Chile.

A stony iron with crystalline granular mixture of olivine and bronzite in the metallic mesh.

An assortment of complete stones, weighing 96 grams, found in 1888. Also a polished fragment weighing 16 grams.

McKINNEY, Collin County, Texas. Fig. 10.

This is a portion of a mass thought to have fallen in 1870. It is covered with a reddish brown, much oxidized crust. Its groundmass is greenish black, compact and fine granular and contains chondrules and metallic grains.

MOCS, Transylvania, Hungary.

Several specimens weighing 273 grams. Fell February 3, 1882, at 4 o'clock in the afternoon. This fall was one of the most remark-

able on record, the number of fragments being estimated as upwards of 3,000, and the aggregate weight as between 174,113 grams and 300,000 grams. The stones were distributed over an area of some three by six miles, according to Fletcher, or an area of 60 square kilometers, according to Koch.

Specimen of Moc sliced on one end, to show the comparative difference in color between the outside crust, which is black, and the inside stone, which when newly cut is almost pure white. The brown stained effect is evidence of the small proportion of nickel and iron which it contains, and very like our earthly material, is subject to rust.

MORRISTOWN, Hamblen County, Tennessee.

Stony iron, found in 1887; date of fall unknown. Several fragments were found, weighing altogether some 16,363 grams. Structure is peculiar, an uneven network of metallic iron inclosing the silicate minerals. The mineral structure is crystalline, variable and more or less broken. The color is a dark gray.

NEJED, (Wadee Banee Khaled), Central Arabia.

Etched slice weighing 825 grams, from a mass weighing 59.4 kilograms, found in 1887, and believed to have been seen to fall in 1863. It is an iron with fairly coarse markings.

NESS County, Kansas. Fig. 11.

This stone is representative of a fall concerning which nothing is known. The first discovery was made in 1898, since which time several others have been found, bringing the total weight up to nearly 10 kilograms. It is a stone meteorite with breccia-like intermediate chondrites.

PLAINVIEW, Hale County, Texas.

This stone is of interest from the fact that the broad side facing the observer was foremost in its flight, as is shown by the "thumb marks," or depressions, and the fine striations radiating outward in all directions. These were caused by the resistance of the atmosphere, which produced sufficient heat to fuse the stone on the immediate surface, the fused material being stripped off as fast as formed, leaving only a thin, black, glassy crust over the still unfused portion.

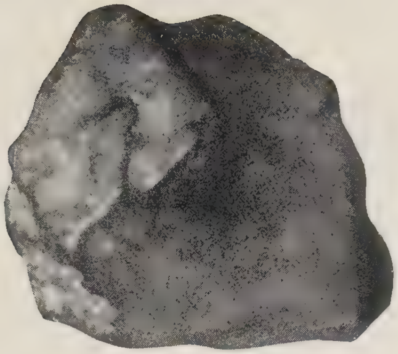


Fig. 11. Ness County Stone.

Fig. 12. Santa Rosa Iron.

SANTA ROSA, Province of Boyaca, Columbia, South America. Fig. 12.

Slice, weighing 3,459 grams, from a mass secured by H. A. Ward in 1906. It is etched and shows brecciated structure and numerous troilite nodules.

TOLUCA (Xiquipilco), Mexico. Fig. 13.

Siderite weighing 4 pounds. Date of fall unknown. Known as early as 1776. Numerous masses of meteoric iron, varying in weight from 300 pounds to minute specimens, have been found in Toluca Valley, and it is highly probable that they all came from the vicinity of Xiquipilco, in the state of Mexico. Many of these masses were used by the native blacksmiths as anvils and for making agricultural implements.

Although this is the first meteoric iron in which the presence of quartz crystals and apatite were proven, there is doubt concerning the occurrence of quartz as an original constituent.

* * *

Upon the case of meteorites is a photograph of the crater around which the Canyon Diablo meteorites were found, one of the moon showing its craters resembling that of the Canyon Diablo, and one of stars with a meteor crossing the field.

CLEVELAND ABBE

Cleveland Abbe, educated in the public schools from his earliest years, was graduated from The College of the City of New York in 1857, a classmate of Professor Werner.

He attained early recognition as a mathematician and as an astronomer. His crowning achievement, however, was in the field of scientific meteorology, which for more than forty years claimed his undivided attention, as professor of meteorology and chief scientist of the Weather Bureau of the United States.

The first weather predictions in the world, based on simultaneous tri-daily reports from all parts of the country were made by him during six months, at the astronomical observatory of Cincinnati, Ohio, of which he was then the director.

After the established success of these predictions our government initiated the Weather Bureau in 1870, and called him to be its scientific head, a position which he retained until his death in 1916.

He would have been poorly equipped for this distinguished career, and for the large output of scientific writing, which won for him the respect of all countries, without the groundwork of deep study of geology and natural history, of astronomy and chemistry, of higher mathematics and of languages, notably Latin, French and German, which he maintained to the end of his life, and without the habit of intense classroom application.

His modest nature sought no rewards, yet the University of Glasgow, at the request of Lord Kelvin, honored him with her LL.D., the Royal Meteorological Society of England awarded him her most distinguished gold medal, and our own National Academy of Sciences gave him the Hartley gold medal "for greatest service for human welfare," in recognition of his establishment of the Weather Bureau of the United States.

As a tribute to him, and in recognition of the achievements of one of the foremost sons of the college, this collection of meteorites has been assembled and presented by one of her alumni as a signal addition to knowledge, in the hope that it may widen, for the student, the ever broadening view of life. Accompanying it was a fund of five thousand dollars, the interest of which was to be wholly at the disposal of the Professor of Geology for any purpose which he considered helpful to his department.

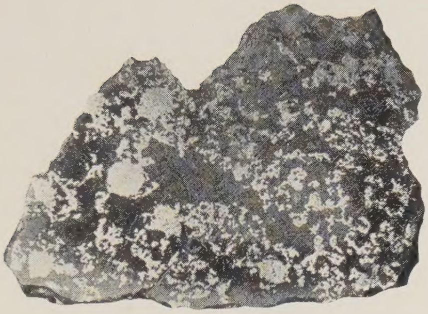
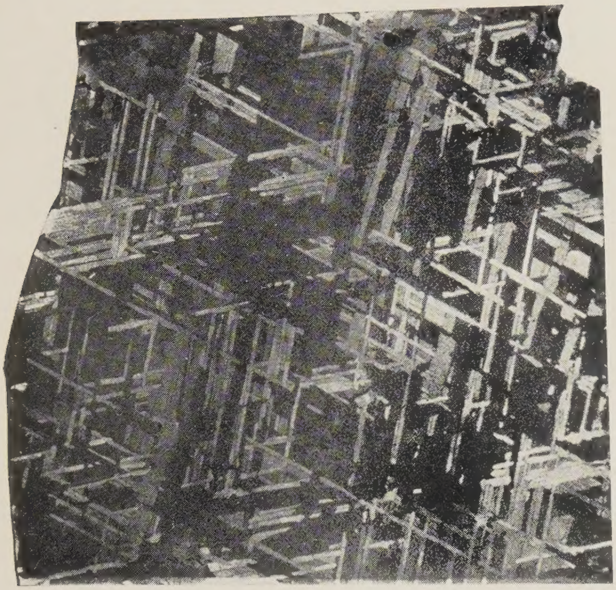


Fig. 13. Toluca Iron.



Nejed Iron, Page 14.